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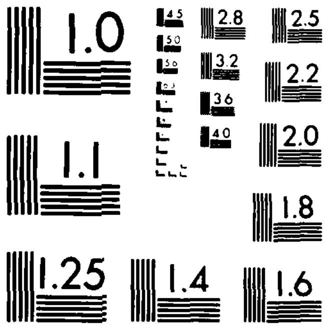

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STRUCTURES REPORT 402

ANALYSIS OF THE DOUBLE OVERLAP FATIGUE SPECIMEN

by

J. PAUL and R. JONES

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ANALYSIS OF THE DOUBLE OVERLAP FATIGUE SPECIMEN

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SUMMARY

In recent years an analogy has been proposed between the behaviour of a bonded overlap joint and a bonded repair. This paper examines the behaviour of the fibre and the adhesive stresses in a bonded overlap joint and shows that the results of previous one-dimensional analyses of this problem are invalid in the vicinity of the gap in the specimen. The fibre and adhesive stresses are also shown to be strongly dependent on the gap size.

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NOTATION

u, v	Displacements of nodes in x or y direction
σ_y, τ	Adhesive peel and shear stresses
g	Gap
σ_u	Unnotched failure stress for the boron-epoxy
a_o	Critical damage zone size
σ_f	Fibre stress
σ_x	Stress in x-direction

1. INTRODUCTION

The Aeronautical Research Laboratories (ARL) in Australia has pioneered the use of adhesively bonded boron fibre reinforced plastic (BFRP) patches to repair cracks in aircraft components [1]. This procedure has been successfully used in several applications to RAAF aircraft, including the field repair of fatigue cracks in the lower wing skin of Mirage III aircraft [2] and in the landing wheels of Macchi aircraft [1, 2]. In each case, repairs were made by adhesively bonding a BFRP patch to the component with the fibres spanning the crack, the aim being to restrict the opening of the crack under load thereby reducing the stress intensity factors and thus preventing further crack growth.

Two approaches have been developed in Australia for the analysis and design of bonded repairs to thin metal sheets. The first approach to be developed is based on the use of the finite element method and is presented in detail in [3]. The second approach is based on a postulated analogy to an overlap joint [4, 5]. It has been shown in [3] that this analogy gives a good approximation for the stress intensity factor at the tip of a patched crack, provided that the crack grows in a self-similar fashion. Experimental work [6] has also shown that the overlap-joint specimens yield data on adhesive material properties which are particularly useful in aiding the choice of adhesive and surface preparation for a bonded repair. Indeed, from the experimental point of view, the overlap joint approach is particularly worthwhile. Unfortunately this paper shows that the approximate theory used in [4, 5] is invalid in the vicinity of the crack (i.e. gap). Consequently the accuracy of the expressions given in [4, 5] for the peak fibre stresses in the repair and the adhesive stresses over the crack, requires further investigation.

2. THE D.O.F.S. SPECIMEN

Let us begin by considering the simple double overlap joint (D.O.F.S.) specimens which are currently used in the joint UK/USA/Canada/Australian demonstrator program on crack patching. The geometry of these specimens is shown in Fig. 1.

A detailed finite element analysis was undertaken for each specimen geometry. The adhesive layer, aluminium, and the boron epoxy were modelled separately. The resultant finite element model consisted of sixty-eight of the eight-noded isoparametric elements. In this idealization the modulus for the aluminium was taken to be $E = 73 \times 10^3$ MPa, $\nu = 0 \cdot 3$, whilst for the adhesive $E = 13 \cdot 5 \times 10^3$ MPa, $\nu = 0 \cdot 35$, and the the boron epoxy the values $E_{11} = 208 \times 10^3$ MPa, $E_{22} = E_{33} = 2 \cdot 5 \times 10^3$ MPa, $\nu_{13} = \nu_{23} = \nu_{12} = 0 \cdot 1677$ and $G_{13} = G_{23} = G_{12} = 5 \times 10^3$ MPa were used.

The resulting variation of the peak fibre stresses and adhesive stresses, and the displacements along the plane AA′ (see Fig. 1) are given in Tables 1 and 2 for several values of the gap parameter g and for a stress of $137 \cdot 9$ MPa applied uniformly to the ends of the aluminium (see Fig. 1).

TABLE 1

Boron DDOF, Adhesive and Fibre Stresses

g (mm)	σ_y (MPa)	τ (MPa)	σ_f MPa Stress Distribution through Laminate	
			Bottom (nodes)	Top (node 4)
8·0	−24·1	−41·3	635·0	472·5
4·0	−19·7	−42·5	670·0	433·0
2·0	−15·5	−43·7	715·0	396·5
1·0	−12·1	−44·9	765·0	371·5
0·25	− 8·2	−46·7	855·0	348·5
0·0	− 6·8	−48·0	930·0	341·0

TABLE 1(a)

Boron DDOF, Displacements Along A1 Face, See Fig. 1(b), in mm

		Nodes							
		9	183	192	209	218	235	7	3
g = 8·0 mm	u	0·02400	0·02393	0·02370	0·02330	0·02267	0·02173	0·02003	0·01132
g = 4·0 mm	u	0·01917	0·01910	0·01887	0·01847	0·01784	0·01689	0·01519	0·00625
g = 2·0 mm	u	0·01671	0·01664	0·01641	0·01601	0·01537	0·01442	0·01272	0·00352
g = 1·0 mm	u	0·01545	0·01538	0·01515	0·01474	0·01410	0·01315	0·01144	0·00202
g = 0·25 mm	u	0·01447	0·01439	0·01474	0·01376	0·01311	0·01216	0·01043	0·00064
g = 0·0 mm	u	0·01413	0·01405	0·01382	0·01341	0·01276	0·01180	0·01006	0·000

TABLE 2

Boron DOF, Adhesive and Fibre Stresses

g (mm)	σ_y (MPa)	τ (MPa)	σ_f MPa Stress Distribution through Laminate	
			Bottom (node 3)	Top (node 4)
8·0	−25·0	−34·5	630·0	600·0
4·0	−22·6	35·0	650·0	570·0
2·0	−19·8	−35·7	685·0	530·0
1·0	−17·0	−36·5	725·0	495·5
0·25	−13·1	−37·1	800·0	453·0
0·0	−10·6	−38·8	895·0	432·5

for overlap joints is not valid in the vicinity of the gap; however, the overlap joint analogy can still be used, and the critical design parameters for crack patching evaluated, provided that a detailed two-dimensional analysis of the joint configuration is undertaken.

4. ACKNOWLEDGEMENTS

This work was done for Dr A. A. Baker as part of the TTCP panel PTP-4 demonstrator program on crack patching. The authors also wish to acknowledge discussions with Dr J. Hart-Smith of the McDonnell Douglas Corp.

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